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(54) Device for automatically positioning and centering a microscope optical head

(57) A device for automatically positioning and centering the optical head of a microscope, for example for surgical use, said optical head being connected to a drive unit; said device analyzes the image framed by the microscope objective by means of an automatic system for analyzing the image light distribution, for example a videocamera connected to a processing circuit and possibly to a microprocessor, then processes it until a reference point of said light distribution is identified by dividing said image into N subzones, then on the basis of information regarding the position of said reference point it controls said drive unit of the microscope optical head to if possible return said reference point to within a predetermined tolerance zone.

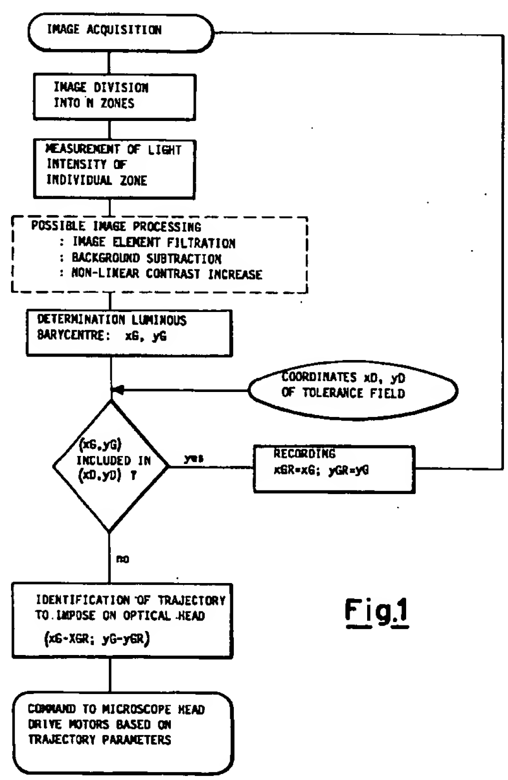

Fig.1

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Description

This invention relates to a device for automatically positioning the optical head of a surgical microscope relative to the operating site.

Microsurgical techniques and methods are widespread in many specialist sectors of medical science, such as neurosurgery, ophthalmology, reconstructive hand and foot surgery etc. The common denominator is the use of an optical microscope in the operating theatre for suitably magnifying the anatomical details of the part subjected to surgery.

An operating microscope consists essentially of an objective and a pair of "tube lenses". When the object to be observed is placed in the focal plane of the objective, these lenses reproduce an intermediate image of it which can be observed and/or magnified by a pair of oculars. Tube lenses and oculars are provided as a pair to allow the object to be viewed stereoscopically.

Normally between the objective and tube lenses there is inserted a revolving turret with Galilean telescopes or a pancratic system to be able to vary, respectively discretely or continuously, the resultant total magnification of the microscope. Typical magnifications are between 5 and 50. Frequently the magnification system is operated by a motorized system, suitably controlled by a keypad.

The optical head of the microscope is completed by a coaxial illumination system for the operating field. Said optical head is mechanically suspended from an articulated arm rigid with a stand rigidly connected to the ceiling or to a suitable base rigid with the floor. To be able to be freely positioned over the operating couch, the microscope is provided with a system for fine translation in the vertical direction (for focusing) and in the two horizontal directions (for image centering). Frequently such movements are effected by electric motors controlled by a pedal board available to the surgeon.

The microscope optical head can be provided with an image divider, making a further two observation channels available. It is normal practice to install an additional pair of oculars for use by a second operator and a photographic or television apparatus for acquiring visual documentation of the microsurgery.

Using a modular system it is possible in reality to install on the same microscope a number of image dividers, and to connect to each of them either an additional pair of oculars or a photographic, television or other apparatus which can be considered useful.

It should be noted that the field of vision on the recording channel is usually smaller than that available to the primary operator, because of the different configuration of the optical systems forming the image. This means that the microscope objective must be centered as accurately as possible on the zone of interest to the operation. In this respect, where the surgeon is still able to "see", it is not automatically certain that the eye of the telecamera or photographic apparatus is able to receive a sharp and reproducible image.

If the area of surgical interest leaves the field of vision of the operator, or of the recording system (for example reproduced on a monitor by a telecamera), the surgeon himself, or rather one of his assistants, operates the translation motors to return the image of interest to the centre of the field of vision. This is not always easy, and in particular could take too much time. It can hence happen that the surgeon loses vision of the field of operating interest for a few moments, with consequent obvious inconvenience, or the loss of important operating stages in the archive of photographic images or visual recording.

The fact of the area of surgical interest leaving the field of vision of the operator can have various causes. In general it can happen either because the site of the surgical treatment has effectively changed or because, although this has remained unchanged, that part of the body on which the operation is being carried out has shifted for strictly anatomical reasons.

A typical surgical operation in which this often happens is vitreo-retinal endoscopic surgery, in which the field of operation is the rear chamber of the eyeball.

During vitreo-retinal endoscopic operations, the surgeon introduces into the eyeball not only the operating instruments but also, according to requirements, draining or infusion probes, or lighting systems such as a fibre optic endoscopic probe.

In this type of operation the entire part on which surgery is to be carried out cannot always fall within the visual and recording field of the microscope. This is even more so when operating with high magnification. It often happens that the position of the microscope optical head has to be readjusted as a result of the shifting of the operation site. Again, because of the anatomy of the organ subjected to surgery (ie the eyeball) and of the considerable freedom of rotation of the eyeball within its socket, it can happen that although the surgery remains on the same portion of tissue, the eyeball undergoes considerable rotation within its socket, for example because of surgical manoeuvres by the surgeon. This can shift the image of interest outside the field of vision.

Given the relative frequency of such movements, reiterated adjustments of the microscope position are required, to the detriment of the attention and comfort of the surgeon, in addition of the quality of the images being acquired.

An object of the present invention is to obviate the aforesaid problems of the state of the art.

A particular object of the present invention is to provide a device to be connected to a surgical microscope which acts on the microscope optical head such as to maintain the image provided by the microscope always properly centered relative to the operating site.

Said objects are attained by a device for automatically positioning and centering the optical head of a microscope for surgical use, said optical head being connected to a drive unit, characterised in that said device analyzes the image framed by the microscope

objective by means of an automatic system for analyzing the image light distribution, then processes it until a reference point of said light distribution is identified, then on the basis of information regarding the position of said reference point of said light distribution it controls said drive unit of the microscope optical head.

During the operation the surgeon has available means (for example a fibre optic endoscopic probe) for illuminating, or concentrating a light beam onto, the zone in which he is operating. The result is that, very roughly, the site of the operation corresponds to the most illuminated zone. On the basis of this assumption the device of the present invention seeks, within the image framed by the microscope objective, the zone or point of highest light intensity, and makes said zone or point correspond to the site of the operation. Alternatively, in a preferred embodiment of the present invention, the device of the present invention calculates the position in horizontal and vertical coordinates of the luminous barycentre of the image as the parameter for locating the operating site with respect to a cartesian reference system rigid with the microscope optical head.

The surgical microscope to which the device of the present invention can be connected must be provided with at least one image divider, so that the same image which the surgeon has before his eyes can be fed to an automatic image analysis system.

Said automatic image analysis system can for example be a videocamera connected to an electronic image processing circuit or a photosensitive matrix connected to a microprocessor.

The videocamera can be either in black and white, providing a standard black/white CCIR signal, or in colour.

A microprocessor for processing the acquired images can be connected to the image analysis system as heretofore described.

This connection can be either direct, without intermediate accessories, or an image memory device can be interposed, from which the microprocessor withdraws the image for analysis subsequent to the time at which the image was acquired and memorized.

In this case a system memory, a system bus with switching devices and an image acquisition card are connected to the videocamera, said card sampling the video signal and memorizing it in a memory bank in the form of an image matrix.

The processed signal from the videocamera, possibly reproduced on a television monitor for explanation and teaching purposes, is then analyzed in parallel by the electronic processing circuit.

To better understand the operation of the centering device of the present invention, reference should be made to the accompanying Figure 1, showing the flow diagram of the actions performed by the device of the present invention.

The microprocessor forming part of the device analyzes the image produced by the videocamera and divides it into N zones or frames.

For each of these N zones or frames the microprocessor measures the light level and memorizes it. Hence with each zone there is associated a value corresponding to the light intensity level of the zone.

After possible additional operations involving light level adjustment, light filtration, possible contrast increase, and subtracting the mean light level of the N zones, the microprocessor is able to calculate the position of the image "luminous barycentre" relative to the system of cartesian axes associated with the microscope optical head. The "luminous barycentre" means the barycentre calculated by assigning to each discrete zone a weight equal to its light level.

The greater the number of zones into which the video or digitalized image is divided the greater the accuracy in identifying the position of said barycentre.

In an alternative form of the present invention, the electronic circuit seeks the brightest point of the image as the centre of the brightest zone of the image, and defines this as the reference point of the image light distribution.

An advantage of the method is that no particular detail of the image has to be recognized and localized in terms of form, scale factor, orientation or chromatic composition, but only a reference point for the luminosity of the scene. This means that the calculation procedures are enormously simplified and accelerated, so as to take place in real time. In this manner the tracking efficiency is largely independent of the effective magnification used, the background brightness, any chromatic dominance, etc.

An additional possibility of seeking and precisely identifying the surgical site is to place on it a distinctive sign, for example an arrow, a geometrical shape, a cross, etc. of colour or brightness considerably different from the surrounding operational environment, of any material suitable for the purpose. The microprocessor provided with the device of the invention must then be designed to recognize at least one shape and/or one colour and possibly a light distribution orientation within the image.

This can be achieved for example by identifying the contours of an entirely connected zone of sufficiently uniform brightness and/or colour, possibly gradually defining said contours ever more precisely using conventional recognition algorithms. On completing this procedure the resultant connected shape is compared with the previously memorized shape to be found. If there is sufficient similarity between said two shapes the microprocessor completes the procedure for identifying the distinctive sign, otherwise it repeats the procedure until identification is achieved.

In this manner the microprocessor is able to associate the exact position of the site to be framed with the recognition of a particular geometrical shape or its possible spatial orientation.

In preferred embodiments of the present invention; the image light distribution is analyzed within a specific spectral band, using wavelength-selective optical filters.

In a much preferred embodiment, said spectral band is located within the visible region of optical radiation, said spectral band having any desired width so as to include only one colour or several colours. In preferred embodiments alternative to this latter, said spectral band is located either in the infrared region or in the ultraviolet region of optical radiation.

At this point, after the indicated procedures, the microprocessor has calculated the coordinates xG and yG within the cartesian reference system rigid with the optical head of the surgical microscope, and having its origin at the geometrical centre of the visual field of the image light distribution reference point, whether this be the luminous barycentre or the brightest point.

The microprocessor now checks whether said reference point lies within or outside a predetermined tolerance zone. Said tolerance zone is represented for example by coordinates $\pm|xd|$ and $\pm|yD|$, or by a single coordinate pD in polar coordinates, determined previously. If it is found that the reference point falls within the tolerance zone, this means that the image is sufficiently centered and there is no need to feed any signal to the optical head drive unit. If instead the reference point does not fall within said tolerance zone, the device has to generate a signal which is then fed to optical head drive unit, which signal must be able to move the microscope optical head until the luminous barycentre of the image again falls within the tolerance zone.

To achieve this, the fastest way is to evaluate the extent and direction (the movement vector) of the movement undergone by the reference point from its previous position (the coordinates of the already estimated reference point are automatically memorized each time the image analysis and processing procedure is repeated).

When said movement vector has been evaluated, the command given to the drive unit is such as to copy said movement vector, ie such as to transmit to the microscope optical head a movement coherent with said movement vector (same direction, same modulus and same sense). In this manner the image is rapidly and effectively recentered on the operating site.

Alternatively, in a second preferred embodiment of the device of the present invention, the said movement vector can be evaluated in a slightly different manner, by taking it as the vector joining the centre of the tolerance zone (defined by the two coordinates xDC= 0; yDC=0) and the last calculated reference point.

Again in this case the command given to the drive unit is such as to copy said movement vector.

The optical head drive unit is composed of electric motors connected to suitable reduction gears. Said electric motors receive their commands from said microprocessor. If said microprocessor is not provided, said image processing circuit can be suitably modified so that it transmits commands to the electric motors to correctly reposition the optical head.

At this point the described image acquisition and processing procedure can be repeated.

The precision and accuracy of the device of the present invention in always returning the microscope optical head to a position such as to ensure image centering on the operation site is also a function of the calculation speed. For equal microprocessor processing capacity and speed, the calculation speed is an inverse function of the number of zones into which the image has been divided. For reasons of symmetry it is advisable for said number of zones to be a perfect square (64, 81, 100 etc.). As the number of zones increases the processsing time increases, however with a large number of zones the resolution and the calculation time can be easily reduced by grouping the zones into groups of 4 or 9 or another number using software.

In a preferred embodiment of the invention, the sampling of the image and the position of the barycentre is done at television frame frequency (50 Hz in Europe), whereas the head traversing times are given by the speed of the motors, which are usually fairly slow.

This means that the slow stage of the process of image recentering on the operating site is controlled neither by the image acquisition and processing procedure nor by the motor speed or the speed of the chosen optical head drive system.

In an alternative embodiment to the aforedescribed, the automatic system for analyzing the image light distribution comprises a photosensitive element arranged to generate signals proportional to the extent of off-centering of said image light distribution from the centre of said photosensitive element, said off-centering being suitably measured along two mutually perpendicular directions.

Depending on the particular case, said photosensitive element can consist of a position-sensitive semiconductor photodiode, an optoelectronic sensor of quadrant or otherwise segmented type, or an optoelectronic image dissector tube.

To make the identification of the reference point in the form of the brightest point or the luminous barycentre of the image simpler and more reliable, it can be advantageous to provide means for increasing the diffusivity and/or reflectivity to optical radiation of all or part of said image. For example said means can consist of diffusive or reflecting marker elements positioned within the image framed by the microscope objective.

In a preferred embodiment of the present invention, said means consist of the actual surgical instruments and devices used for the operation, suitably treated to be of greater brightness.

In this description reference has so far been made only to the use of the surgical microscope controlled by the device of the present invention for ophthalmic surgery, and in particular vitreo-retinal surgery.

It should however be noted that the device of the present invention can be of help in any surgical operation with the aforedescribed problems and require-

ments. Neurosurgery and reconstructive plastic surgery can be mentioned as examples.

The device of the present invention can also be applied in an industrial field where microscopic investigations are required with the aid of endoscopic illumination, for example in electronics, and in the preparation of components such as thick film and thin film printed circuits.

Claims

1. A device for automatically positioning and centering the optical head of a microscope, for example for surgical use, said optical head being connected to a drive unit, characterised in that said device analyzes the image framed by the microscope objective by means of an automatic system for analyzing the image light distribution, then processes it until a reference point of said light distribution is identified, then on the basis of information regarding the position of said reference point of said light distribution it controls said drive unit of the microscope optical head.

2. A device as claimed in claim 1, characterised in that said automatic image analysis system comprises a videocamera connected to an electronic image processing circuit.

3. A device as claimed in claim 1, characterised in that said automatic image analysis system comprises a videocamera connected to an electronic image processing circuit, and also connected to a microprocessor, to a system memory, to a system bus and switching devices, and to an image acquisition card which samples the video signal and memorizes it in said memory in the form of an image matrix.

4. A device as claimed in claim 1, characterised in that said automatic image analysis system comprises a photosensitive matrix connected to a microprocessor.

5. A device as claimed in claim 1, characterised in that said reference point of the processed image light distribution is the luminous barycentre of said image.

6. A device as claimed in claim 1, characterised in that said reference point of the processed image light distribution is the brightest point of said image.

7. A device as claimed in any one of the preceding claims, characterised in that said microprocessor identifies the position of the reference point of the analyzed image light distribution by the following steps:

   - dividing the image into N zones;
   - measuring the light level of each point;
   - calculating said luminous barycentre by assigning to each discrete zone a weight equal to its light level.

8. A device as claimed in claim 7, characterised in that after measuring the light level of each zone, the mean light level of the N zones is subtracted.

9. A device as claimed in claims 1 to 6, characterised in that said microprocessor identifies the position of the reference point of the image light distribution by the following steps:

   - dividing the image into N zones;
   - measuring the light level of each point;
   - calculating said reference point as the centre of the brightest zone of the image.

10. A device as claimed in claim 7 or 9, characterised in that N is a perfect square.

11. A device as claimed in claims 1 to 6, characterised in that said microprocessor identifies the position of the reference point of the image light distribution by recognizing at least one shape and possibly a light distribution orientation within the image.

12. A device as claimed in any one of the preceding claims, characterised in that said image light distribution analysis is effected within a specific spectral band, limited by the use of wavelength-selective optical filters.

13. A device as claimed in claim 12, characterised in that said spectral band is located within the visible region of optical radiation.

14. A device as claimed in claim 12, characterised in that said spectral band is located within the infrared region of optical radiation.

15. A device as claimed in claim 12, characterised in that said spectral band is located within the ultraviolet region of optical radiation.

16. A device as claimed in claim 8 or 9, characterised in that said drive unit for said optical head is controlled by the microprocessor in the following manner:

   - a check is made to determine whether said image light distribution reference point lies or does not lie within a previously determined tolerance zone;
   - if said check is positive, no command is fed to the drive unit by the microprocessor;
   - if said check is negative, the microprocessor calculates a movement vector and controls the

drive unit to cause said optical head to move in accordance with and in the same sense as said movement vector.

17. A device as claimed in claim 16, characterised in that said movement vector calculated by the microprocessor is the vector joining the position of the reference point of the immediately preceding check to the new position of the reference point.

18. A device as claimed in claim 16, characterised in that said movement vector calculated by the microprocessor is the vector joining the centre of the tolerance zone to the new position of the reference point.

19. A device as claimed in claim 1, characterised in that said automatic image analysis system comprises a photosensitive element arranged to generate signals proportional to the extent of off-centering of said image light distribution from the centre of said photosensitive element, said off-centering being measured along two mutually perpendicular directions.

20. A device as claimed in claim 19, characterised in that said photosensitive element is a position-sensitive semiconductor photodiode.

21. A device as claimed in claim 19, characterised in that said photosensitive element is a quadrant or segmented optoelectronic sensor.

22. A device as claimed in claim 19, characterised in that said photosensitive element is an optoelectronic image dissector tube.

23. A device as claimed in claim 3, characterised in that said drive unit for said optical head is composed of electric motors connected to reduction gears, said electric motors receiving commands from said microprocessor.

24. A device as claimed in claim 2, characterised in that said drive unit for said optical head is composed of electric motors connected to reduction gears, said electric motors receiving commands from said electronic circuit.

25. A device as claimed in any one of the preceding claims, characterised by using means for increasing the diffusivity and/or reflectivity to optical radiation of all or part of said image.

26. A device as claimed in claim 25, characterised in that said means consist of diffusive or reflecting markers positioned within the image framed by the microscope objective.

27. A device as claimed in claim 25, characterised in that said means are surgical instruments and devices suitably treated to be of greater brightness.

28. A device as claimed in any one of the preceding claims, for use in ophthalmic surgery.

29. A device as claimed in any one of the preceding claims, for use in vitreo-retinal surgery.

30. A device as claimed in any one of the preceding claims, for use in neurosurgery.

31. A device as claimed in any one of the preceding claims, for use in reconstructive plastic surgery.

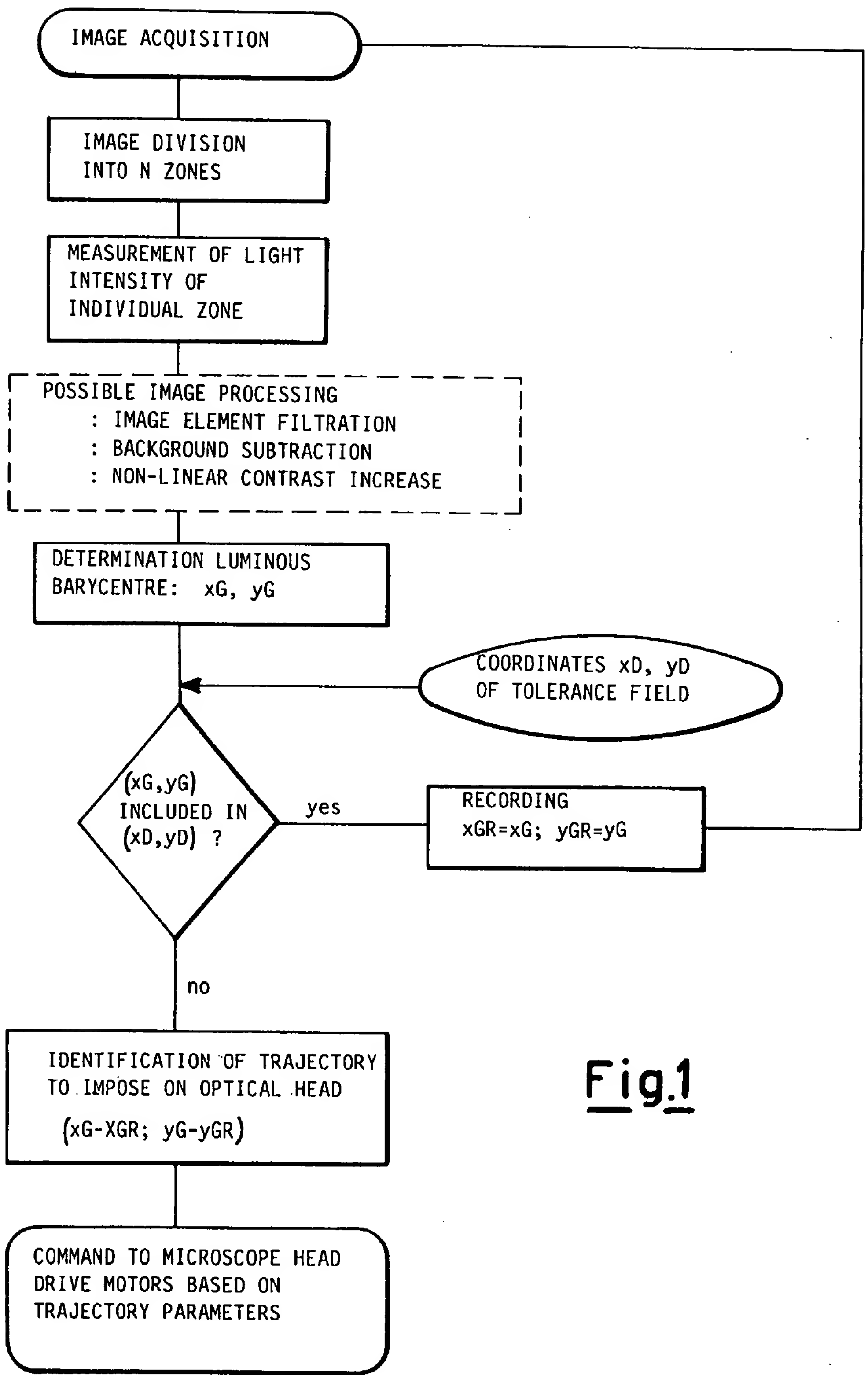
IMAGE ACQUISITION
IMAGE DIVISION INTO N ZONES
MEASUREMENT OF LIGHT INTENSITY OF INDIVIDUAL ZONE
POSSIBLE IMAGE PROCESSING
: IMAGE ELEMENT FILTRATION
: BACKGROUND SUBTRACTION
: NON-LINEAR CONTRAST INCREASE
DETERMINATION LUMINOUS BARYCENTRE: xG, yG
COORDINATES xD, yD OF TOLERANCE FIELD
(xG,yG) INCLUDED IN (xD,yD) ?
yes
RECORDING xGR=xG; yGR=yG
no
IDENTIFICATION OF TRAJECTORY TO IMPOSE ON OPTICAL HEAD (xG-XGR; yG-yGR)
COMMAND TO MICROSCOPE HEAD DRIVE MOTORS BASED ON TRAJECTORY PARAMETERS

Fig.1

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 20 1069

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP-A-0 229 581 (BIOCONCEPT SARL) 22 July 1987 * abstract * * column 1, line 37 - line 49 * * column 2, line 36 - line 53; figures 1,5,6 * ---	1-4,6, 23,24	G02B21/26 G02B21/24 G02B21/36
X	DE-A-36 20 887 (MESSERSCHMITT BOELKOW BLOHM) 23 December 1987 * column 2, line 58 - line 60 * * column 3, line 8 - line 44; claims 1,3,12; figure 1 * ---	1-4,19	
A	US-A-5 216 500 (M.J. KRUMMEY ET AL.) 1 June 1993 * abstract * * column 1, line 19 - line 23 * * column 1, line 48 - line 63 * * column 5, line 1 - line 20; figure 3 * ---	1-4,25, 26	
A	APPLIED OPTICS, vol. 31, no. 31, 1 November 1992, pages 6684-6689, XP000310810 CABER P J ET AL: "EFFECT OF DETECTOR NOISE ON THE POSITIONING ACCURACY OF AN AUTOFOCUS SYSTEM" Page 6684 - "Autofocus System Description"; page 6688 - "Conclusion" -----	1-4,13, 19-21	TECHNICAL FIELDS SEARCHED (Int.Cl.6) G02B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	15 July 1996	Hessen, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document